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Comparison of two methods of natural regeneration of lodgepole pine in south central Montana

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A COMPARISON OF TWO METHODS OF NATURAL REGENERATION OF LODGEPOLE PINE IN SOUTH CENTRAL MONTANA

by

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CHAPTER I

INTRODUCTION

For many years lodgepole pine has been considered a weed species. Recently, however, lodgepole has come into greater use for pulpwood, small poles, and lumber. The wood of lodgepole has physical characteristics similar to that of ponderosa pine. Considering that Montana has 4.7 million acres of lodgepole type, this species has a bright future.

Extensive stands of lodgepole pine are found on well drained soils, in areas of low mean temperatures and plentiful summer rains. Early root and crown development of lodgepole is poor, resulting in small and frail seedlings. Consequently an adequate supply of moisture is essential to survival. In addition, lodgepole pine is an intolerant species and its seedlings require mineral soil, full sunlight, and little competition if they are to survive.

Fire plays an important role in the natural reproduction of lodgepole pine stands. Many stands contain seed stored in serotinous cones. Fire creates temperatures necessary for the release of seed and prepares seed beds favorable to germination. Unfortunately, site preparation is often too thorough. Seed beds of scarified soil and the seed supply are abundant, resulting in overstocked stands. Consequently, stands containing upwards of 10,000 stems per acre are common.

Similar problems are incurred in the regeneration of lodgepole pine stands following clearcutting. In most cases lodgepole slash is mechanically laid close to the ground where the serotinous cones are opened by heat from terrestrial solar radiation. Large quantities of scarified soil created in logging and site preparation treatments, coupled with the abundance of seed contained in serotinous cones, results in dense stocking.

Two common methods of site preparation, broadcast burning and piling in windrows and burning, have been tried for the regeneration of lodgepole pine in the past. Broadcast burning exposes mineral soil and destroys some seed. Usually, though, site preparation is too thorough and dense stands of reproduction are produced. In a few cases a hot fire may destroy the seed source and stocking is nil. Piling in windrows and burning is the currently recommended procedure, but this method introduces an additional factor of poor seedling distribution. Dense reproduction will often occur between the windrows with reproduction within the windrows lacking.

The abundance of seed held in persistent serotinous cones in a typical stand hinders attempts to control stand densities. Consequently, foresters are becoming interested in new site preparation methods that might control stocking levels. By controlling site it is possible that conditions of moisture, light, and temperature can be created that are detrimental to general seed germination and seedling survival.

Brush choppers, which have been used successfully in Southern forestry practice, have recently been introduced to Montana in an attempt to overcome the problems associated with lodgepole pine regeneration. The chopper is a 20,000 pound drum, with attached cutting blades, which is pulled behind a large tractor. The tractor blade falls standing slash and the drum breaks it into small pieces, crushing it into the ground (Plates 1 and 2, page 4). Fuel volumes are not reduced using the chopper but the fire hazard is reduced in the altering of fuel distribution. Theoretically, the abundance of slash, coupled with small amounts of mineral soil, will result in conditions favorable to limiting germination and seedling establishment.

Piling and burning and redistribution of slash using the rolling chopper are two methods of site preparation and slash disposal used for lodgepole pine regeneration in south central Montana. The purpose of this study was a comparison between these two methods to find out which results in regeneration at more favorable stocking levels. Of primary interest were site preparation, seedling densities and distributions, and vegetational competition. Secondly, site preparation and competing vegetation were evaluated in their relation to seedling regeneration and mortality.

PLATE 1

THE MARDEN BRUSH CHOPPER

PLATE 2

SLASH TREATED WITH THE MARDEN BRUSH CHOPPER

CHAPTER II

LITERATURE REVIEW

I. HISTORY OF UTILIZATION

Le Barron (1952) outlined a brief history of lodgepole pine utilization in Montana:

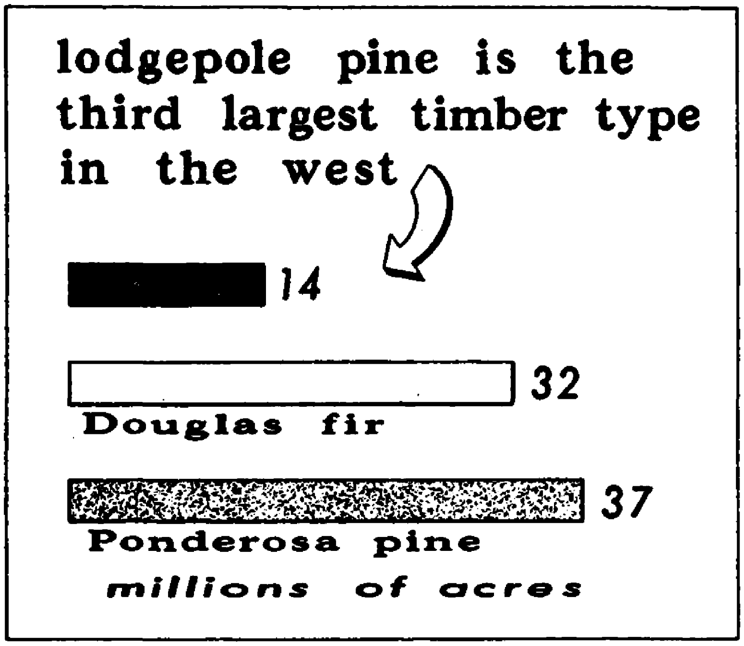
> The pioneer miners, railroad builders, and ranchers, who entered Montana between 1860 and 1880, relied heavily upon lodgepole pine (Pinus contorta) as a prime source of wood for their occupational requirements. The railroad consumed literally millions of hewn lodgepole pine cross ties. The miners used immense quantities for stulls, lagging, and charcoal. The ranchers built thousands of miles of corrals and jackleg fences from this same tree that the Indians found so well suited to tepee construction that it has been named "lodgepole pine." Cutting continued at a high though probably diminishing rate until about 1930. It should not be forgotten that at one time the Deerlodge National Forest ranked first in volume of cut and stumpage receipts among the national forests of the Northern Region. Then a variety of economic factors caused the substitution of other woods and other materials for lodgepole pine in Montana; and cutting, except for strictly local consumption, almost ceased.
>
> About 1945, lodgepole pine again rather abruptly was brought back into the timber market. This time the chief bulk product is pulpwood for high-grade paper pulp, and the highest stumpage value product is transmission line poles. Furthermore, lodgepole pine is increasing in importance as a lumber species. Today, it seems to be assured of permanent markets for several important primary products.

Considering that there are 14.5 million acres of the lodgepole type in the Northwest, 32.4% of which is in Montana (Figure 1), it is obvious that lodgepole pine has been a neglected species. The problem has apparently been one of economic processing of the usual small size

FIGURE 1

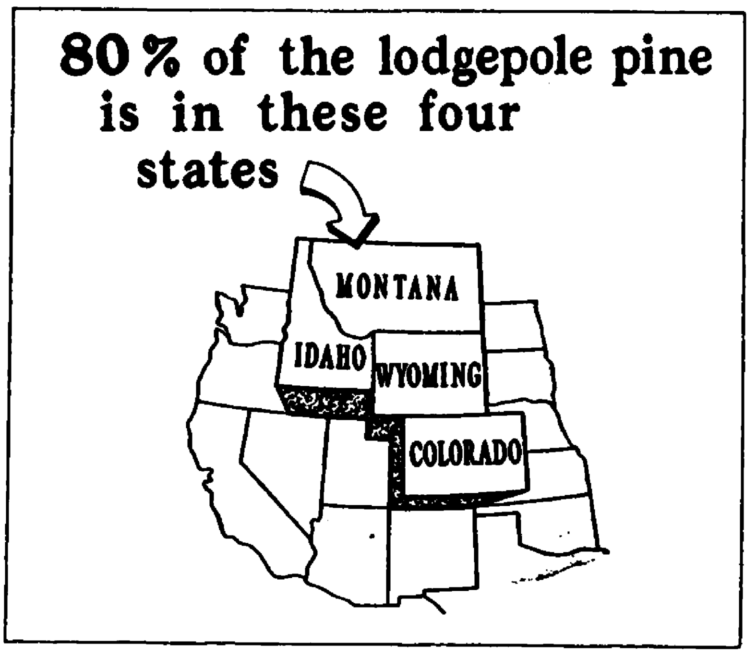
THE RESOURCE

LODGEPOLE PINE IS AN IMPORTANT WESTERN TIMBER SPECIES......



There are 14.5 million acres of lodgepole pine type in the United States. From the standpoint of area, it ranks third behind the Douglas-fir and ponderosa pine types in the West.

...AND IT GROWS MAINLY IN THE ROCKY MOUNTAINS.



11.6 million acres of the type are in four Rocky Mountain States.

Montana	4.7
Idaho	3.1
Wyoming	1.9
Colorado	1.9
Total	11.6

Source: Wikstrom, 1957.

classes associated with lodgepole pine compared with those of larger timber species. The recent trend towards higher utilization of lodgepole pine timber is a reflection of shortages in more sought after species. Still, in 1955, we harvested only one-fifth of the allowable cut for the mountain states (Wikstrom, 1957), suggesting the presence of lingering prejudice against this species and of insufficient engineering advancements in the utilization of small size classes of timber.

Since the timber situation is changing to the advantage of lodgepole pine, we can begin to emphasize its attributes for lumber. While lodgepole does not yield enough select boards to share the market for select material, the grade recovery is certainly satisfactory and the lumber should be in demand for many uses (Wikstrom, 1957). The physical properties of lodgepole pine lumber are compared with ponderosa pine in Figure 2, page 8. Boards of these species are very similar and could be used interchangeably for many uses and should cost the same (Wikstrom, 1957).

II. THE HABITAT

Lodgepole pine is one of the most widespread species in the Rocky Mountain Region (Critchfield, 1957). It grows with ponderosa pine at elevations as low as 3,000 ft. and with whitebark pine and subalpine fir at elevations exceeding 7,000 ft. (Trappe and Harris, 1958). It grows from southeastern Alaska and the Yukon Territory south to

FIGURE 2

LODGEPOLE PINE COMPARES FAVORABLY WITH PONDEROSA PINE IN IMPORTANT PHYSICAL PROPERTIES

	Ponderosa pine	Lodgepole pine
Weight--pounds per cubic feet (8 percent moisture)	27.5	28.2
Strength--static bending, fiber stress at proportional limit, P.S.I. (12 percent moisture content)	6,300	6,700
Shrinkage based on dimensions when green; dried to 6 percent moisture content.		
Tangential (percent)	5.0	5.4
Radial (percent)	3.1	3.6
Hardness--load required to imbed 0.444-inch ball to ½ its diameter, pounds (12 percent moisture content)	450	480

Source: Wikstrom, 1957.

Northern Baja California and east to the Black Hills. Of the four subspecies of lodgepole pine, this study is concerned only with the inland form found from the Yukon down to Colorado.

Lodgepole pine is typically found in areas where the summers are fairly dry and precipitation is likely to be deficient for a short period during the growing season. Best development occurs where precipitation is 21 inches or more, but extensive stands occur where precipitation is only 18 inches (U.S.D.A. Handbook 271, 1965).

Average July temperatures are between 55 and 63°f. Seasonal temperatures may range from 100 down to -55°f.

In southern Montana lodgepole pine is found between 6,000 and 10,500 ft. elevation. It may be found under a wide variety of topographical conditions, but makes its best growth on basins, flat ridgetops, and gentle north and east slopes (Trappe and Harris, 1958). Good stands are found on soils derived from granite, shale, and sandstone. Seedlings of lodgepole pine are frail and in the first two or three months root development is minimal (Tarrant, 1953). Therefore, lodgepole is best adapted to sheltered sites with loose, moist, well drained soils.

III. LIFE HISTORY

Lodgepole pine is widely regarded as a fire species, with inherent properties enabling it to capitalize on the effects of fire on forest vegetation. The ability to reproduce itself after fire, and to replace tree species not capable of reproduction after fire, is due to the closed-cone habit (Critchfield, 1957) (Plate 3, page 10). Throughout the intermountain region this serotinous habit is widespread. Lotan (1967 and 1968), in studies near West Yellowstone, Montana, and Island Park, Idaho, found the incidence of trees bearing predominantly serotinous cones to be 37.8, 57.5, 48.0, and 23.0% in four stands. Apparently the degree of cone serotiny within a stand of

PLATE 3

THE SEROTINOUS CONE HABIT IN LODGEPOLE PINE

lodgepole pine is dependent upon the fire history within that stand. Even-aged stands originating by fire would undergo a strong genetic selection through establishment from seed released from serotinous cones by fire. Uneven-aged stands established over the years from seed released from ~~seed~~ non-serotinous cones would be selective for the open cone habit.

The serotinous habit of a lodgepole pine cone is due to the production of a resin about the margin of the cone scales which seals the scales. The melting point of this seal is approximately 143.5° f.

This is above the range of normal summer temperature, but almost any forest fire is likely to generate temperatures high enough to break the cone seal (Critchfield, 1957). A great seed flight directly follows a fire. The abundance of seed that is freed and the ideal germinating conditions created in burns accounts for the high density levels which so often exist (Smithers, 1961). On a burn in Montana a single mill acre plot was stocked with 765 ten to eleven year old trees (LeBarron, 1952). In other studies there have been as many as 175,000 eight year old trees per acre following wildfire (U.S.D.A. Handbook 271, 1965).

Lodgepole pine is rated a prolific seeder. Boe (1954) stated that good cone crops can be expected at 1-3 year intervals with light crops intervening. Throughout Montana lodgepole pine cone crops are fair to good for 1-9 consecutive years, followed by 1-4 years of poor crops. Studies in Montana have shown numbers of viable seed to be 20-25 per cone (U.S.D.A. Handbook 271, 1965). Averages of 50,000 and 21,000 seed per tree from old and new cones together were found on areas in Idaho and Colorado (Clements, 1910). Bates (1930) observed an annual yield of 320,000 seed per acre for an area in Colorado while Lotan (1967 and 1968) observed yields of 0.8, 1.8, 1.0, and 3.2 million seed per acre on areas very near the study area for this thesis.

Lodgepole pine may begin to produce seed at an early age

(Crossley, 1956). In open grown stands, trees produce seed at 5-10 years while in heavier stocked stands seed is produced beginning at 15-20 years. Crossley suggested the possibility that the closed cone habit is restricted to older stands, with the open coned habit being restricted to young stands. Apparently in some stands there is a genetic factor which allows trees that have produced open cones at a young age to begin producing closed cones. If this assumption is correct, it may have a valuable survival influence for lodgepole pine. Understocked stands would fill in from seed released from open cones, gaining full stocking of the site. As the stand approaches maturity the serotinous cone aspect takes dominance, providing for successful regeneration in the event fire destroys the stand.

The basic factors affecting lodgepole pine germination and establishment include moisture, temperature, and light (Smithers, 1961). Best seedling establishment occurs in full sunlight and on mineral soil or disturbed duff free of competitive vegetation. On deep litter accumulations germination may take place, but survival is poor because of rapid drying of litter and duff in the droughty summer months and the failure of seedling roots to become established in a permanent moisture supply (Smithers, 1961). Ackerman (1957) found better survival on scarified mineral seedbeds than on burned seedbeds (52 vs. 40%). Poorer survival was probably due to high rates of absorption of solar radiation by blackened soil and the subsequently higher temperatures realized on this strata. Ackerman also stated that lodgepole seedlings are sensitive to root competition from other plant species.

The regeneration of lodgepole pine following wildfire or silvicultural harvest may fail for many reasons. The three legs of the regeneration triangle are a seed source, proper seedbed, and conditions suitable for survival (Plate 4, below). With lodgepole pine, the seed source can be either from seed released annually from open

PLATE 4

THE REGENERATION TRIANGLE FOR LODGEPOLE PINE: SEED CONTAINED IN SEROTINOUS CONES, MINERAL SEEDBED, AND CONDITIONS FAVORABLE TO SURVIVAL cones or from seed contained in serotinous cones (Crossley, 1956; Lotan, 1967 and 1968). Dependence on regeneration from open cones is questionable in the Rocky Mountains. Crossley (1955), in a study of lodgepole pine in Alberta, found the annual seedfall from open cones to be only 550-2450 seed per acre, with an average of 1517. Crossley states that this seedfall is inadequate for purposes of restocking. Even in Montana, where the incidence of the open-cone habit is more frequent (approximately 50% vs. 20% for Alberta), I feel that seedfall is probably insufficient. On the other hand, seed contained in serotinous cones may range upwards of three million per acre in southern Montana forests, providing an often overabundant seed source for regeneration. Cochran (1969) stated some conditions unfavorable to the establishment of lodgepole pine seedlings:

1. animal damage may be important--many small animals, especially pocket gophers, congregate in clearcuts.
2. seed dispersal may be inadequate.
3. heat injury and drought may cause some mortality.
4. severe night frosts during germination of 13°f. can cause death of individual seedlings.

IV. GROWTH AND YIELD

In lodgepole pine most of the growth factors--volume, diameter, and height--are strongly influenced by stand density, regardless of site (Smithers, 1956). Stand volume is inversely related to the number of stems per acre because diameter and height are affected by the number of stems per acre (Figures 3 and 4, pages 16 and 17). In stands of more than 200-300 stems per acre the proportion of volume in larger trees decreases as density increases, masking the relationship between age and volume (Trappe and Harris, 1958). Basal area, however, is fixed by the site quality. A better site is able to support a stand of timber with a higher amount of basal area and the basal area will be constant regardless of stand density.

Lodgepole pine is a pioneer species characterized by rapid early height growth and surpasses most of its associated tree species (Trappe and Harris, 1958) (Plate 5, page 18). As juvenile growth slows down, the other tree species usually catch up and surpass the lodgepole pine. After its early height growth lodgepole pine increases its crown area and good growth is maintained long after it reaches a stagnated condition (Trappe and Harris, 1958).

Lodgepole pine can maintain itself almost indefinitely in a mixed forest. Its variable seed habit allows it to shed seed from open cones into openings created in a closed forest and the serotinous habit insures survival following wildfire.

Yields of 12,000-15,000 bd. ft. per acre are considered good in old-growth lodgepole pine stands, most trees at 140 years are 7-13 inches in diameter and 60-80 ft. high (U.S.D.A. Handbook 271, 1965). Under management conditions yields may be as high as 23,000 bd. ft. per acre at 120 years.

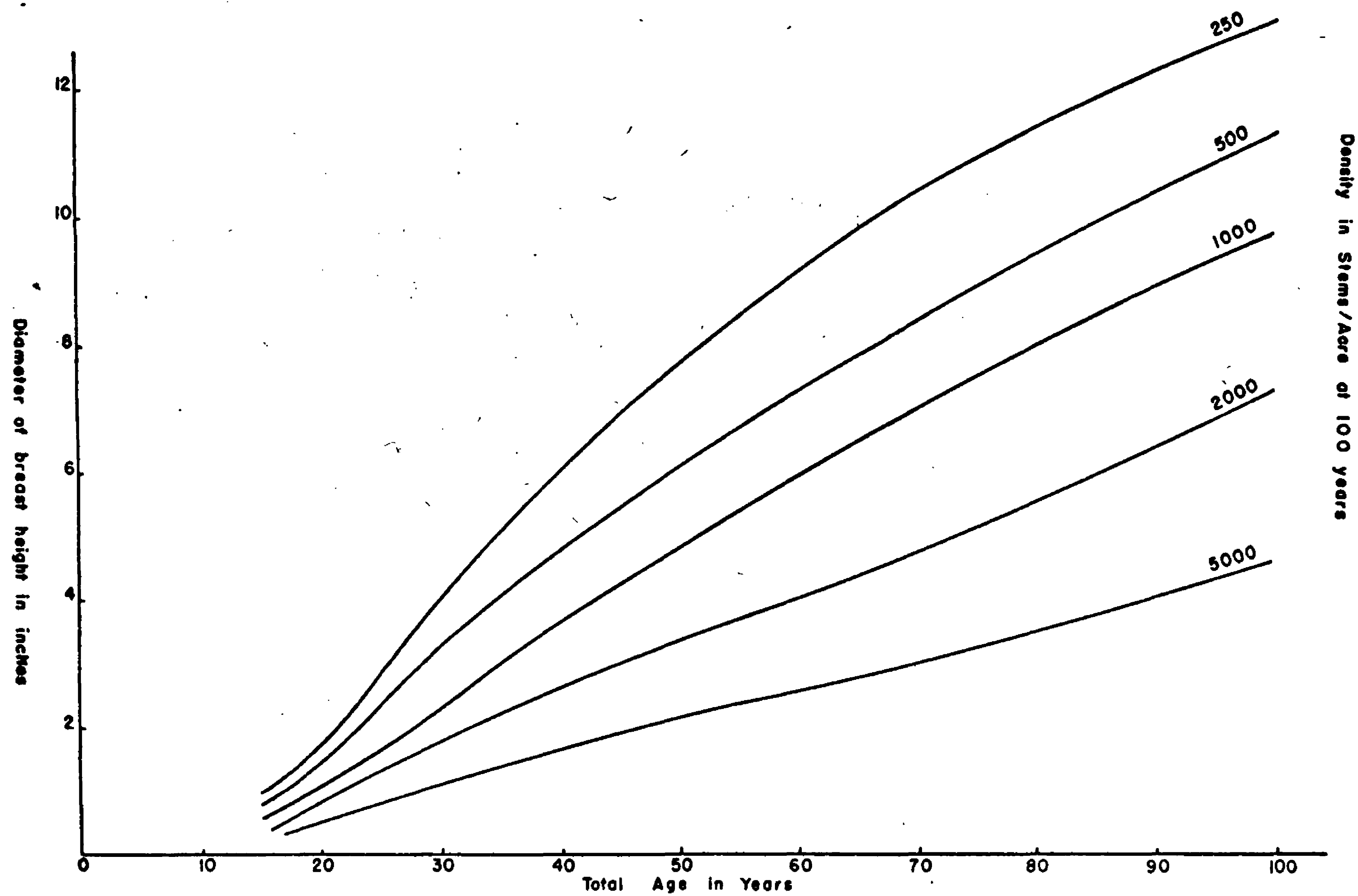


FIGURE 3: AVERAGE DIAMETER OF THE 100 LARGEST TREES IN LPP STANDS OF VARING DENSITY.
Source: Smithers, 1961.

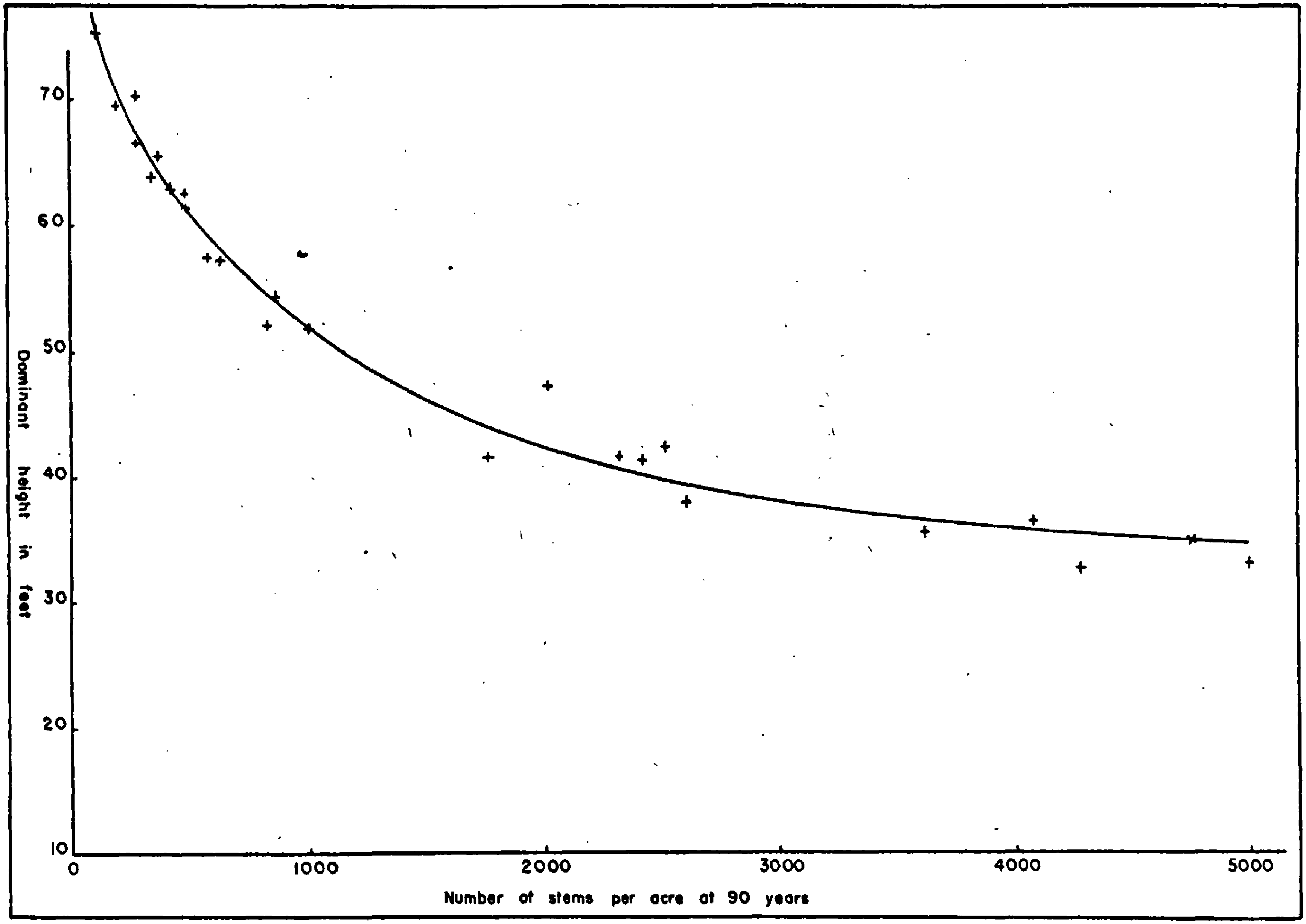


FIGURE 4: THE EFFECT OF STOCKING ON THE DOMINANT HEIGHT OF 90-YEAR-OLD LODGEPOLE PINE ON A DRY SITE.
Source: Smithers, 1961.

PLATE 5

FORTY INCHES OF LEADER GROWTH IN A YOUNG LODGEPOLE PINE

V. SILVICULTURAL METHODS

Lodgepole pine stands are unique in their exhibition of both the serotinous and non-serotinous cone habits. Lotan, 1967, said that stands which contain both habits provide flexibility to the forester in the selection of cutting methods. Seed contained in serotinous cones allows clearcutting in large blocks, because closed cones readily open if logging slash is handled carefully. Non-serotinous cones provide seed from standing timber, so that methods such as strip clearcutting or shelterwood can be used. In Montana, however, there are two factors which tend to eliminate dependency on seed contained in non-serotinous cones.

First, stands in the intermountain area have a high incidence of cone serotiny. The annual seedfall from open cones is insufficient for regeneration purposes. However, there is usually plenty of seed stored in serotinous cones for silvicultural systems designed to take advantage of this factor.

Secondly, lodgepole pine stands in Montana have a very high infection rate from lodgepole mistletoe. Dwarf mistletoe parasitizes all size classes of lodgepole pine, but its spread is most critical during the period of stand regeneration (LeBarron, 1952). Regeneration must be isolated from sources of infection if the stand is to be allowed to approach its growth potential. This means that large clear-cuts should be the rule to retard infection with mistletoe.

For proper management of lodgepole pine in western Montana, we must therefore rely on silvicultural methods designed to take advantage of seed stored in serotinous cones.

One of the first conditions that should be considered by any system is extraction of the seed from the serotinous cones. Broadcast burning of slash (Plate 6, below) has been used frequently in an attempt to obtain proper regeneration of lodgepole pine in Montana. Slash is laid close to the ground and burned following drying. Cones are opened either by scorching by the fire or by exposure to solar radiation at the soil surface. This method provides abundant seedbed for regeneration but unfortunately the temperatures incurred during slash burning are often very hot, destroying lodgepole seed stored in the slash. In studies of regeneration on broadcast burned plots, Le Barron (1952) stated that the comparatively poor distribution of seedlings on the ground following broadcast burning results from the burning of seed on more

PLATE 6

A BROADCAST BURNED CLEARCUT

of the ground surface. In the White Sulphur Springs study he found seedbeds where slash had been burned to be understocked. Overall stand density was determined to be 725 trees per acre. This would be considered ample regeneration if the trees were well distributed, but mill acre stocking was only 18%. Mill acre stocking is probably a more valid measure than absolute numbers of seedlings per acre, and 65-75% is about optimum. Unfortunately, understocking is the usual rule following broadcast burning of slash on clearcuts. If burning could be limited to a smaller part of the ground, perhaps by burning following rain or snow, the method might give better results. But slash may not be effectively reduced in this manner and regeneration can be over-abundant.

Other methods of slash disposal have been (1) lopping and scattering and (2) dozer piling and burning of slash. The first method reduces slash hazard by distribution of flammable materials close to the ground surface, thus hastening decomposition and limiting rate of fire spread. The latter method destroys most of the slash through burning. Both methods are designed to place slash containing serotinous cones close to the ground. The cones are then opened by heat from solar and terrestrial radiation (Lotan, 1968). Crossley (1956) said that the factors affecting the opening of cones are the following:

> The cone attached to slash on the forest floor will attempt to come to a heat balance within its changing environment, and the equilibrium temperature it will reach will depend upon a number

of factors. They include:

1. The amount of direct and reflected solar and atmospheric radiation received, which will in turn vary directly with the altitude, the position of the sun in relation to its zenith, the nature of the air mass hovering over the area, and the degree of crown canopy.
2. The intensity of illumination per unit area of cone.
3. The amount of terrestrial radiation which will depend upon the height of the cone above the ground and the proximity of neighboring solid objects such as branches and foliage.
4. The heat lost through long-wave radiation from the cone.
5. The heat lost through conduction from the cone to the air enveloping it. This is a variable source of heat loss since the exposure to ventilation and the greater the air movement, the greater such a loss will be.

Slash disposal by lopping and scattering and piling and burning have a distinct effect on the seed supply and the survival of the seedlings. Lopping and scattering does not provide enough mineral soil for an adequate seedbed and regeneration is low despite an adequate seed supply (Ackerman, 1962). Piling and burning, on the other hand, exposes abundant amounts of mineral seedbed as well as providing adequate quantities of seed from cones borne on slash scattered during the process of piling. Usually scarification is too thorough and regeneration is too dense (Crossley, 1956).

As an alternative to these methods foresters have become interested in the brush chopper as a method of slash disposal in lodgepole pine clearcuts.

Speed is of primary importance for maximum efficiency and production from the brush chopper. With increased speed the drums bounce slightly, thereby increasing the cutting action of the blades

PLATE 7

DOZER PILING OF SLASH PRIOR TO BURNING

(Albert, 1966; DeCelle and Wolfe, 1969). Forest stands containing a mixture of size classes, such as are found in Montana, reduce the speed of the chopper considerably, the operator being forced to constantly adapt the motive power of the tractor to changing conditions. In stands with uniform size classes the driver is able to maintain constant speed. There is a limit to the size of material that can be handled effectively. When tree diameters approach six inches the chopper is not able to cut through the material.

On the Cedar Creek roller thinning project the chopper was found feasible for any species under 40 years of age (size is important here) on ground up to 30% grade (DeCelle and Wolfe, 1969). The slash hazard was of little consequence after the first summer season, all of the slash was close to the ground and broken fine. These results may not hold for treatment of stands containing larger sizes of material.

CHAPTER III

STUDY AREA DESCRIPTION

I. AREA DESCRIPTION

The investigation reported here was conducted in an area of extensive lodgepole pine stands located on the eastern foothills of the Gravelly Range. This area is approximately 33 miles south of Ennis, Montana, in Township 11 South and Range 1 East, Principle Meridian, Montana. Two clearcuts, unit #6 in sections 4, 5, 8, and 9 and unit #1 in section 16, were established for this study. Unit #6 encompasses about 250 acres while unit #1 is approximately 175 acres in area. Both are located on relatively flat benches. The study location is shown in Figure 5, page 26.

The topography is characterized by high bluffs of nearly 1,000 ft. towering above the Madison River, interrupted periodically by deep V-shaped valleys. Ridge tops are typically flattened, often forming extensive butte-like benches. Elevation ranges from 6,000 ft. along the terraces of the Madison River to 7,000 ft. on the study clear-cuts and up to 10,000 ft. at the top of the peaks of the Gravelly Range to the west. Slopes range from extremely gentle on the benches to nearly vertical on the bluffs facing the Madison River and its tributary streams.

UNITED STATES
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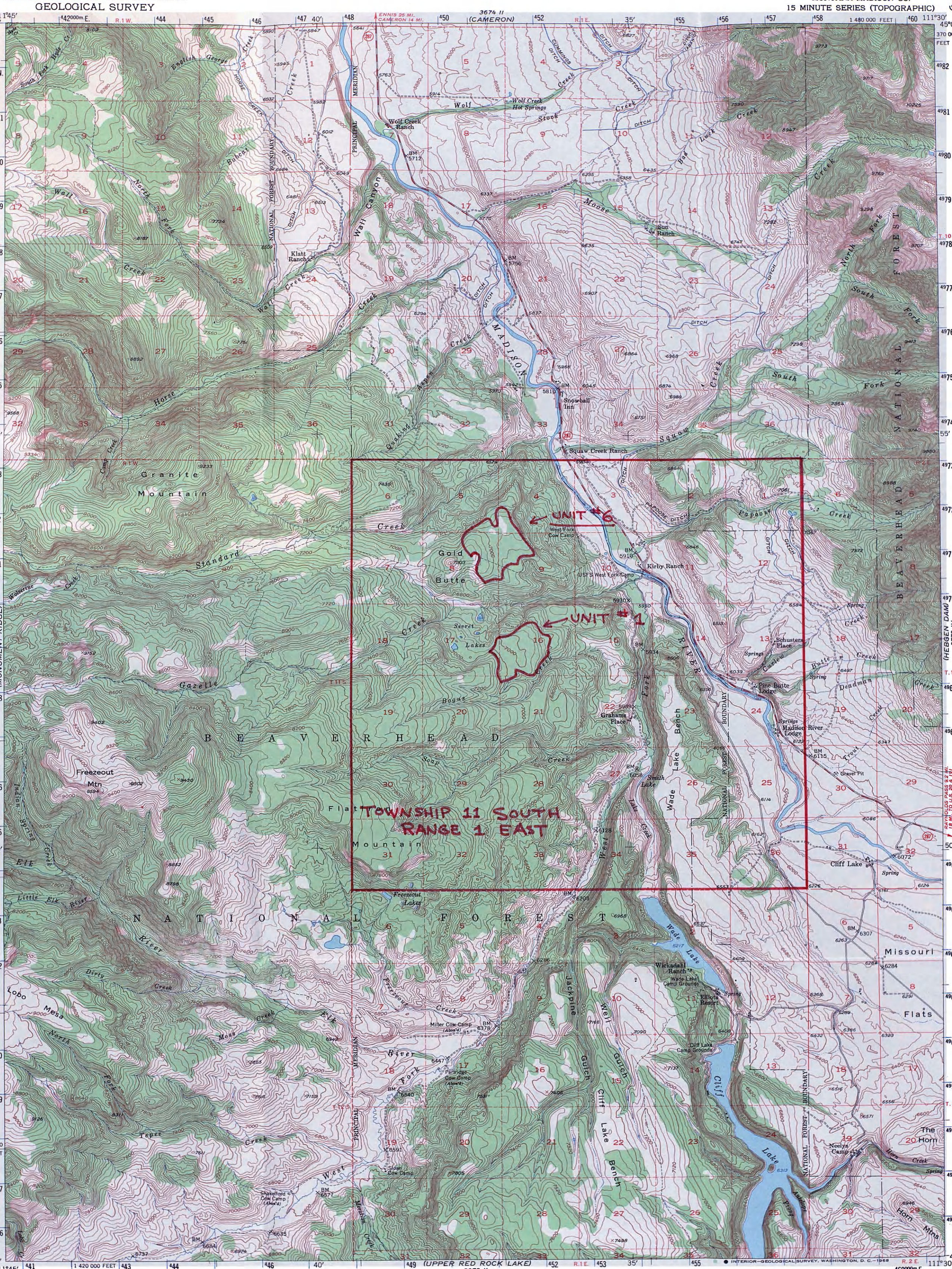
GEOLOGICAL SURVEY

CLIFF LAKE QUADRANGLE
MONTANA-MADISON CO.
15 MINUTE SERIES (TOPOGRAPHIC)



Stereo compilation by Fairchild Aerial Surveys, Inc. for the Bureau of Reclamation
Field examination and publication by the Geological Survey as part of the Department of the Interior program for the development of the Missouri River Basin

Control by USGS, USC&GS and Fairchild Aerial Surveys, Inc.

Topography from aerial photographs by stereoplanigraph methods. Aerial photographs taken 1947. Field check 1950

Polyconic projection. 1927 North American datum
10,000-foot grid based on Montana coordinate system, south zone

Dashed land lines indicate approximate locations
Land lines unsurveyed in T. 9 S.-R. 1 W., T. 11 S.-R. 1 W., T. 12 S.-R. 1 W., and T. 10 S.-R. 2 E.

Unchecked elevations are shown in brown

1000-meter Universal Transverse Mercator grid ticks, zone 12, shown in blue

UTM GRID AND 1950 MAGNETIC NORTH DECLINATION AT CENTER OF SHEET

SCALE 1:62500

CONTOUR INTERVAL 40 FEET
DATUM IS MEAN SEA LEVEL

THIS MAP COMPLIES WITH NATIONAL MAP ACCURACY STANDARDS
FOR SALE BY U. S. GEOLOGICAL SURVEY, DENVER, COLORADO 80225 OR WASHINGTON, D. C. 20242
A FOLDER DESCRIBING TOPOGRAPHIC MAPS AND SYMBOLS IS AVAILABLE ON REQUEST

QUADRANGLE LOCATION

ROAD CLASSIFICATION
Medium-duty
Light-duty
Unimproved dirt
State Route

CLIFF LAKE, MONT.
N4445-W11130/15
1950
AMS 3673 I–SERIES V794

Soils on the two study units are derived from a variety of parent materials. The area has been subject to a variety of geologic phenomena, ranging from volcanic extrusion, to sedimentation, to alluvial deposition by the Madison River. The main composition of the underlying rock is rhyolite, with occasional outcroppings of pumacite. In the western edges of both units there is a layer of rounded quartzite and granite gravel that was deposited thousands of years ago when the Madison River flowed at this elevation. In general, the soils are poorly developed. Little profile development is observed and there is a high occurrence of rock in all horizons. Moisture content should be relatively high, however, due to the presence of substantial amounts of silts and clays in the soil profile.

The climate of this region can be characterized as cool and moderately moist. Precipitation records kept at Gold Butte Saddle, which is located between the two units, show an average annual rainfall for the past three years to be approximately 28 inches. Most of this precipitation falls as snow. Records for the months of May through October show only 10.72 inches of rain occurring in these six critical months of seedling establishment (these data were collected in personal correspondence with Terry Johnson, Forester, Madison Ranger District).

II. STAND DESCRIPTION AND HISTORY

Until recently the entire area encompassed by the Gravelly Range and east to the Madison River has been essentially a defacto wilderness area. The area was opened to logging only six years ago. Until then, the only use was for grazing by cattle and especially sheep, watershed protection, recreation, and limited local timber consumption. Extensive road systems have now been developed in the area bounded by Standard Creek on the north, the West Fork of the Madison on the south, and the Gravelly Range on the west.

PLATE 8

TOPOGRAPHY BEST SUITED TO LODGEPOLE PINE

Pure stands of lodgepole pine type dominate the timber found in this region. The best stands are found on benches, in basins, and on gentle to moderate north and east facing slopes (see Plate 8, page 28). Douglas-fir increases in importance and old-growth stands can be found on dry south and west facing slopes. Old-growth stands of Engleman spruce and subalpine fir are found in sheltered stream bottoms. Young spruce and fir can also be found scattered in the subcanopy of lodgepole pine stands on benches and north facing slopes. Fire has an important influence on these stand compositions. Approximately 90-100 years ago extensive fires destroyed much of the timber except for some of the old fire resistant Douglas-fir stands and some of the spruce and fir stands located in the more protected creek bottoms. Seed contained in serotinous cones permitted abundant regeneration of lodgepole pine at the expense of other fire intolerant species. These lodgepole stands are now approaching maturity and are beginning to break up. Scattered spruce and fir are found throughout and in a few more centuries, barring natural or artificial disaster, may develop into the climax spruce and fir forest for the region.

III. HABITAT TYPES

A portion of the study was concerned with the development of an adaptation of Daubenmire's habitat type classification (Daubenmire, 1968) to the study area. Overstory and understory composition of established plots were used to develop a habitat type association table for the area (see Table 1, page 31). From this table the presence of one classic and three variations of Daubenmire's habitat types (h.t.s), as developed for northern Idaho, were determined (see Plates 9, 10, 11, and 12, pages 32 and 33). The *Pseudotsuga menziesii*- *Symphoricarpos albus* h.t. followed the definition closely (Daubenmire, 1968). It is found on steep dry slopes of southeast to southwest exposure. The *Pseudotsuga menziesii*- and *Abies lasiocarpa*- *Pachistima myrsenites* "southern phase" h.t.s were named for lack of a better definition. They both have similar understories and appearances to the classical *Pachistima* unions except for the lack of "key" species; *Clintonia uniflora* and *Galium triflorum* have ranges that do not extend this far east and south. *Pachistima myrsenites* is present, however, and is used in this case to separate these h.t.s. Until a better name can be found to put on them these two h.t.s will be referred to as the "southern phase" of the *Pachistima* union. The *Pseudotsuga menziesii*- *Pachistima myrsenites* "southern phase" h.t. is found on moderate east and northeast exposures and may be found on gentler southerly slopes. The *Abies lasiocarpa* version is found on gentle to steep north slopes. The *Abies lasiocarpa*- *Vaccinium scoparium* "*Calamagrostis rubescens* phase" h.t. is found on gentle slopes of all aspects. It differs from the classical *Abies lasiocarpa*- *Vaccinium scoparium* h.t. (Daubenmire, 1968) in the large amounts of *Calamagrostis rubescens* contained in the h.t. found in this region.

TABLE : HABITAT TYPE ASSOCIATION TABLE (ENNIS, MONT.)

CLIMAX OVERSTORY	PSEUDOTSUGA MENZIESII						ABIES LASIOCARPA																							
CLIMAX UNDERSTORY UNION	SYMPHORICARPOS ALBUS				PACHISTIMA M. (SOUTH PHASE)		VACCINIUM SCOPARIUM (CALAMAGROSTIS PHASE)													PACHISTIMA MYRSENITES (SOUTHERN PHASE)										
Plot	10	12	8	9	11	6	3	4	12	16	15	13	14	7	1	13	9	10	5	5	16	1	15	4	7	2	8	2	6	3
Section	8	8	14	14	14	14	14	14	14	14	14	14	14	14	14	9	8	14	14	5	4	9	9	4	5	4	8	14	4	4
Elevation	7120	6960	7000	6920	6800	7000	7100	7140	6850	7000	7000	6850	6920	6960	7000	6920	7100	6900	7100	7000	6960	6960	6850	7000	7040	6960	7100	7040	6960	6960
Aspect	180	180	190	110	90	100	340	120	10	260	70	30	70	90	0	80	360	60	90	—	180	260	200	320	345	50	310	320	350	360
Slope	1	25	15	30	25	10	10	2	3	2	1	5	10	25	0	10	5	5	20	0	1	2	5	5	5	10	20	15	25	25
Block	6	6	1	1	1	1	1	1	1	1	1	1	1	1	1	6	6	1	1	6	6	6	6	6	6	6	6	1	6	6
Basal Area	—	263	183	287	201	109	212	293	227	121	190	195	206	257	170	169	174	195	189	198	85	92	186	199	205	109	157	222	145	213
--- TREES ---																														
Abies Lasiocarpa							0 0 +	1 0 2	0 1 2	0 + +	0 + +	0 0 +	0 0 +	0 0 +	0 0 +	0 0 1	0 0 +	0 0 +	0 0 1	0 0 +	+ + +	0 + 2	0 0 +	0 0 +	0 + 3	0 + 3	0 + 2	0 1 2	0 1 2	0 + 1
Picea Engelmannii										0 0	1		0		0 0	0 0 1			0 0 1		0 0 2		0 0 +			0 0 +	0 + 2		0 0 2	0 + 1
Pinus Albicaulis			0 0 +			0 0 +					0 0 +			0 0 1	0 0 +				0 0 1		0 0 1		0 0 1							
Pinus Contorta	+ + +	2 2 1	+ 2 3	1 1 1	+ 2 2	0 2 2	2 2 1	2 2 2	1 3 2	3 1 3	+ 2 2	2 2 2	0 3 3	3 2 1	1 3 2	0 3 3	0 3 3	0 2 3	+ 2 2	0 3 3	0 2 3	0 2 2	0 3 3	0 3 3	0 2 2	2 2 2	2 2 2	2 2 2	1 2 3	0 3 3
Pseudotsuga Menziesii	+ + +	2 2 3	+ 0 2	2 2 2	+ 1 3	+ 0 2	+ 2 2	+ 0 1	+ + 3	0 1 1	0 1 2	+ + 2		+ + 2	0 0 +	0 0 1	0 0 1	0 0 1	0 0 1	0 0 +	0 0 2	0 0 2	1 0 2	0 0 +	+ + 1	+ + 2	0 + 3	0 1 2		0 1 1
--- SHRUBS ---																														
Acer glabrum																														
Amelachier alnifolia						1																								
Arctostaphylis uva-ursi			+	1	1																+	1				1				
Artemesia tridentata	3			1																										
Berberis repens	1	2	1	2	1		1	1	1	1		1	1	1		1		1		1		2	1			1				1
Chymaphylla umbelata										1		2	+				1			+		1		1				+	1	1
Lonicera utahensis			1	1	2	1	1	1				1	1				1	1		1	+				1		2	1	2	
Pachistima myrsenites																				2	1	1	2	1	2	1	2	+	1	2
Pyrola spp.		1		1	1	1			1		1	1	1		+	1	1	1	1	1	+	1	1		1	1	1	1	1	1
Ribes inermi			1		1																									
Rosa gymnocarpa		2		1	1															1							1	1		
Rosa woodsii					1	1																								
Shepherdia canadensis		1	1																		2						2		3	+
Spirea betulifolia	2	2	2	1	1		1	1	1	2	1	1		1		1	2	+	1	2	1	1	1	1	2	2	2	1	1	2
Symphoricarpos albus	3	2	+	2																+					2					
Vaccinium scoparium					1	2	3	2	3	3	3	3	3	3	2	3	3	2	3	2	3	3	3	3		1	2	2	2	1
Vaccinium membranacium				2	3	3	3	1	2		1	1	2	1	2	2	1	3	2	1		2	2	3	+	3	2	3	3	3
--- FORBS ---																														
Agoseris glauca	1										1	+	1																	
Antenaria racemosa																												1		
Apocynum androsaemifolium				1																										
Arnica latifolia		1	1		1		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1		1	1	1	1	1	1
Aster conspicuous	2	2	+	1	1	1	1	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1		1
Balsamoriza sagitata	2																													
Campanula rotundifolia		1							1	1	1	+																		
Collinsia parviflora	2		+																											
Collomia linearis	2																													
Epilobium angustifolium	2				1	1			1		1	1	1	1	1	1		1		1	1	1	1	1						1
Erithronium grandiflorum							1																							
Fragaria virginiana	1	1	+		1	1	1	1		1		1	1	1	1		1	1	1		1	1		1			1		1	1
Geranium viscosisimum	1							1		1		1																		
Goodyera oblongifolia																												1	2	1
Heiracium albertinum			1	1	1		1		1	1	1	1	1		1	1	1				1	1	1			1		1		1
Lupinus parviflorus	2								1	2	1	1	1	1	1	1	1		1		1	1	1							1
Oxytropus spp.	2		+	1	1	1			1	1	1	1	1	1	1	1	1	1	1			1	1	1		1		+		1
Potentillia glandulosa	1																													
Potentilla gracilus	1																													
Pterospermo andromedea			+									+																		
Senecio trianguiarus																				1										
Smilacina racemosa	1	1		+						1						1	1													
Solidago occidentalis										1					1															
Thalictrum occidentalis				+											1														1	
Viola spp.	1									1	1					1	1			1									1	1
·· GRAMINOIDES ···																														
Agropyron spp.	3																											+		
Bromus spp.	3	1								1																				
Calamagrostis rubescens	3	2	2	2	2	2	3	3	2	3	2	2	3	2	3	3	2	2	1	3	2	2	2	2	2	2	1	2	1	1
Carex concinoides			1	1	1			1								1												1		
Carex geyerii	3			1	1		2	2	2	1	2	2	1	1	2	1	1		1		1	1	1					2	1	+

KEY TO COVER VALUES

- \+ species not located in plot but found in the area
- 1 occasional; cover less than 5 %
- 2 common; cover 5–25 %
- 3 abundant; cover > 25 %

For trees there are three values given (for example; 2 2 3):

- the first value is the cover for trees larger than 12 inches diameter
- the second is for trees 4–12 inches
- the third is for trees < 4 inches

PLATE 9. PSEUDOTSUGA MENZIESII- SYMPHORICARPOS ALBUS H.T.

PLATE 10. PSEUDOTSUGA MENZIESII- PACHISTIMA MYRSENITES "SOUTHERN PHASE" H. T.

PLATE 11. ABIES LASIOCARPA- PACHISTIMA MYRSENITES "SOUTHERN PHASE" H. T.

PLATE 12. ABIES LASIOCARPA- VACCINIUM SCOPARIUM "CALAMAGROSTIS RUBESCENS PHASE" H. T.

The two clearcuts which comprise this study are composed primarily of the _Abies lasiocarpa - Vaccinium scoparium_ "_Calamagrostis rubescens_ phase" h.t. Unit #1 varies in the presence of a small area of the _Pseudotsuga menziesii - Symphoricarpos albus_ h.t. on a dry steep southeast slope on the western edge of the clearcut. This, however, was not contained in the portion of the clearcut that was studied. Unit #6 also has an area of this h.t. on the knob on its western edge. Several of the study plots on this clearcut do fall within this h.t. The _Abies lasiocarpa - Pachistima myrsenites_ "southern phase" h.t. occurs on gentle north and northeast slopes along the northern and eastern edges of unit #6.

IV. SELECTION OF STUDY AREA

The only brush chopper working in Region 1 in 1966 was on the Madison Ranger District. Results looked promising, but some questions remained unanswered as to the effectiveness of the chopper. One question was how much regeneration can be expected on areas treated with the brush chopper. The Forest Service, cooperating with the Montana Forest and Conservation Research Station, decided on this study for answering some of these questions. Since the Madison District had the most experience in the Region with the chopper, they were asked if any areas were available for the study. District personnel pointed out areas that had been treated with the chopper in 1966 and

1967 and the areas that could be set up in 1968. The only areas available for treatment in 1968 were blocks 1 through 6 on the Gazelle-Standard Creek timber sale. Blocks 1 and 6 were selected because of similarities in topography and because they could easily be divided in half so comparisons between slash piling and burning and slash chopping could be measured. Block 1 was desirable in that it was visible from the road and served as a good demonstration area.

CHAPTER IV

EXPERIMENTAL DESIGN

Two units of 175 and 250 acres were selected for this study. Each unit was logged in 1967 and site preparation techniques were applied in 1968 (see Table 2). Each unit was divided in half according

TABLE 2

UNIT LOGGING AND TREATMENT DATES

Treatment	Logging Date	Treatment Date
#1 P&B	Jan. & Feb., 1967	piled--July, 1968 burned--Oct., 1968
#6 P&B	June & July, 1967	piled--Aug., 1968 burned--Oct., 1968
#1 MBC	Jan. & Feb., 1967	chopped--Sept., 1968
#6 MBC	June & July, 1967	chopped--Sept., 1968

to topography, an N 66° E line being placed along the ridge located in each clearcut. In the southern half of each clearcut the slash was dozer piled and in the northern half the slash was treated with the Marden Brush Cutter (see Plates 13 and 14, pages 37 and 38). Therefore, there are two replicates of each treatment, one replicate located on each clearcut. The comparison between the two site preparation

PLATE 13

PANORAMIC VIEW OF UNIT #1

The southern half has been treated with piling and burning. The northern half has been treated with the Marden Brush Cutter. (South is on the right side of the picture.)

PLATE 14

PANORAMIC VIEW OF UNIT #6

The southern half has been treated by piling and burning and the northern half with the Marden Brush Cutter. (South is located on the right side of the picture.)

techniques involved observations that were indirect measurements of variables which include competitive vegetation, site preparation, and lodgepole pine regeneration. Data were collected so that statistical comparisons could be made between treatments, within treatments, and between plots within treatments.

I. PLOT LOCATION

Plots were established in 1967 by Lee F. Werth, a graduate student in Forestry, University of Montana. Fifty plots were located on each of the two replicates per treatment, giving two hundred plots total for the study. Plot selections were random along preselected plot lines, which ran parallel to the dividing line of each unit. Unit #1 P&B and MBC treatments each had two lines of plots while unit #6 treatments had only one plot line each. It was believed that the rather homogenous nature of the topography on unit #6 in comparison with unit #1 allowed for establishment of less sample lines on unit #6.

During the burning phase of the pile and burn treatment of unit #1 the fire spread into the brush chopper side of the clearcut, destroying some of the plots on this treatment. It was therefore necessary to establish new plots on the MBC treatment. This was accomplished by offsetting part of the second line 200 feet northward and establishing the required number of additional plots along this new line.

Two lines on unit #6 P&B were not of sufficient length for the establishment of 50 plots. Six plots were established on a third line to meet the required total number of plots.

II. WEATHER

A hydrothermograph and rain gauge were located in the center of each clearcut in the summer of 1969. These data were helpful in establishing climatic similarity between the two units as well as in relating information gained on this study to other areas. They were also helpful in predicting abnormal summer weather in comparison with average annual measurements.

III. SITE PREPARATION AND COMPETITIVE VEGETATION

Fifty, square, mill acre plots were used to measure site preparation and competitive vegetation on each treatment replicate (plate 15). The frame was composed of an aluminum tube grid system consisting of ten vertical and ten horizontal wires, forming 100 point intercepts. The frame was suspended above the plot and a wire probe was dropped along each of the 100 intercepts. The sum of the hits on a plant or other variable represented the percent cover for the particular plot. Field work sheets were designed to contain information for hits on mineral soil, mulch, rock, duff, slash, and each of the plant

PLATE 15

SQUARE MILL ACRE FRAME

species occurring on a plot. To obtain an accurate picture of site preparation, secondary hits were recorded when the probe recorded a primary hit on vegetation. A primary hit represents the first object struck in the drop of the probe. If this primary hit was on a plant, then the second object struck after the probe passes through the vegetation was called a secondary hit. This allowed calculation of site preparation on a 100% cover basis, while giving a separate interpretation of vegetational cover.

IV. SEEDLING REGENERATION AND MORTALITY

Circular mill acre plots were used to measure seedling regeneration and mortality (Plate 16, below). These plots were located on the same points used for square, mill acre plots. Seedling species and numbers were recorded to give stand densities. Frequencies are also important to estimate seedling distribution. Distribution, as expressed by seedling frequency, is probably a more critical measure of site preparation than absolute numbers of seedlings per acre. Data sheets were designed so that seedlings could be recorded as to the type

PLATE 16

CIRCULAR MILL ACRE FRAME

of strata they emerged from (mineral soil, duff, etc.). An attempt was also made to correlate seedling mortality with possible causal factors. An eight inch ring was placed about each dead or dying seedling. Competing vegetation, type of strata, or any other factor occurring within this circle of influence which may have some bearing on the cause of death was recorded.

V. STUMP SURVEY

Unfortunately, this study was initiated after completion of logging and site preparation treatments on the two clearcut units. Therefore, information on stand composition, density, and stocking and the incidence of cone serotiny were lacking. To compensate for this error, a survey of the residual stumps of commercial timber on each clearcut was conducted. These data were intended to give an approximate reconstruction of the original stand compositions. A 40 ft. diameter plot was used to measure the basal area of all stumps eight inches or greater in diameter. The midpoints for each of these plots were the same as those used for the determination of site preparation. Unfortunately, it was impossible to gain any estimate of the composition of unmerchantable timber due to destruction of small stems during slash treatments.

VI. HABITAT TYPE SURVEY

Sixteen forty-foot diameter plots were established within standing timber about the perimeter of each unit for the purpose of a habitat type survey. Information collected on each plot included measurements of stand composition, elevation, slope, aspect, and numbers and species of regeneration. Also within each plot three trees, one each of dominant, intermediate, and suppressed crown position, were destructively sampled to determine age, height, crown length, and numbers of seed contained in serotinous cones. David Johnston, working under a National Science Foundation Undergraduate Research Grant, used this information to develop a linear regression equation for predicting the number of seed contained in serotinous cones. He decided that tree diameter is the best indicator of the number of seed per tree. The formula he developed is $Y = (33X-147.7)^2$, where Y is equal to the square root of the number of seed and X is the tree diameter. Y must be multiplied by 0.49, however, since a mistake was made in including both serotinous and nonserotinous cones in the formula prediction. The overall incidence of cone serotiny was 49%. This formula has been used in this study to estimate the number of seed per acre on each of the habitat type plots as well as for an estimate of seed contained on merchantable timber within the clearcuts.

Overstory and understory stand compositions of each plot were used to develop a habitat type association table for the study area (Table 1). This information was used in the study area description chapter of this thesis (pages 29-34).

VII. ANALYSIS OF DATA

Comparison of treatments data were analyzed using the two sample t test. Major variables are seedling densities, mineral soil, duff, slash, and vegetation.

CHAPTER V

RESULTS

I. WEATHER

Weather data, including rainfall, temperature, and humidity, were recorded during the period June 30 to August 18, 1969 (Table 3). Total rain and temperatures between the two units showed no significant differences. There were differences in relative humidity, however. This was caused by improper calibration of one of the hydrothermographs, the difference being approximately 6%. Data were not recorded in 1970. Similarity in weather patterns between the two units being established.

TABLE 3

WEATHER STATION DATA: 6/30 - 8/18, 1969

Unit	Rain Total	Mean Maximum Temp.	Mean Minimum Temp.	Mean Maximum Humidity*	Mean Minimum Humidity*
#1	3.04"	73.2°C	46.2°C	71.8%	28.5%
#6	3.10"	74.1°C	46.1°C	77.2%	33.1%

*There is a difference in calibration between the two hydrothermographs of approximately 6%.

Table 4 shows the monthly precipitation at the Forest Service Weather Station in Ennis, Montana, for the months May through October for the past three years. The year 1969 was relatively wet in comparison to the other years, 12.18 inches falling for the six months in comparison to an average of 10.72 inches. Of special importance is the amount falling during the three critical drought months of June, July, and August. A total of 7.95 inches of rain fell for these three months in 1969, while the three year average is only 4.91. This observation correlates with the low amounts of drought mortality for the summer of 1969, as will be shown later. The amount of rain for 1970 does not differ from the three year average. However, the rainfall for August

TABLE 4

INCHES OF PRECIPITATION AT FOREST SERVICE WEATHER STATION, ENNIS, MONTANA

	1970	1969	1968	Average
May	2.08	1.21	2.99	2.09
June	1.43	3.71	2.49	2.53
July	2.89	1.26	0.35	1.50
August	0.53	2.68	2.42	1.88
September	1.60	1.50	1.51	1.54
October	0.93	1.82	0.78	1.18
TOTAL	9.46	12.18	10.51	10.72

Source: Terry Johnson, Madison Ranger District.

was very low, only 0.53 inches falling vs. the 1.88 three year average. This dry month may have been severe enough to create large amounts of drought mortality during that month.

II. SITE PREPARATION AND COMPETITIVE VEGETATION

Pile and Burn Treatments

The numbers and frequencies of seedlings on each of the P&B treatments (Table 10, page 57) leads one to expect differences in the data on site preparation (Table 5, page 49). Unfortunately, this is not the case, at least not at first glance. The amount of mineral soil, usually the best indicator of site disturbance, is almost the same for the two units. Observations in the field indicated that unit #1 P&B was more disturbed than unit #6 P&B and the data was expected to support these observations. The data does indicate the expected differences if rock and mulch are considered. Several investigators were employed to collect site preparation data and it was discovered that considerable variation occurred in each individual's interpretation of mulch. It would be better to eliminate this bias by classifying mulch and rock as mineral soil. The sum of rock, mulch, and mineral soil for unit #1 P&B is 40.08% while the sum for unit #6 P&B is 33.80% (Table 6, page 50). This indicates the soil of unit #1 P&B is more disturbed, but there can be shown no significant difference in mineral

TABLE 5

SITE PREPARATION & COMPETING VEGETATION

(PRIMARY & SECONDARY SITE HITS COMBINED)

MEANS & STANDARD DEVIATIONS

DATA IS ON A PERCENT BASIS

		SITE PREPARATION						COMPETING VEGETATION
		MINERAL SOIL	MULCH	ROCK	DUFF	SLASH	TOTAL SITE HITS	
UNIT #1 P&B	$\bar{X}$	26.66	6.90	6.48	35.72	23.76	73.70	26.36
	$\overline{SD}$	23.94	4.92	9.74	22.39	14.69	19.36	19.15
UNIT #6 P&B	$\bar{X}$	26.36	3.34	3.08	39.46	26.36	61.36	38.78
	$\overline{SD}$	26.80	7.67	4.23	20.12	18.70	21.20	20.50
UNIT #1 MBC	$\bar{X}$	9.22	0.76	1.34	35.08	53.00	66.94	31.84
	$\overline{SD}$	18.89	2.25	3.51	18.52	22.25	18.01	18.63
UNIT #6 MBC	$\bar{X}$	13.82	5.08	0.76	32.22	47.94	64.98	34,78
	$\overline{SD}$	18.45	6.93	1.26	18.40	20.82	14.38	15.49

TABLE 6

SITE PREPARATION & COMPETING VEGETATION
(PRIMARY & SECONDARY SITE HITS COMBINED)
MEANS & STANDARD DEVIATIONS
(DATA IS ON A PERCENT BASIS)

		SITE PREPARATION			COMPETING VEGETATION
		MINERAL SOIL	DUFF	SLASH	
UNIT #1 P&B	$\overline{X}$	40.08	35.72	23.76	26.36
	$\overline{SD}$	27.47	22.39	14.69	19.15
UNIT #6 P&B	$\overline{X}$	33.80	39.46	26.36	38.78
	$\overline{SD}$	28.56	20.12	18.70	20.50
UNIT #1 MBC	$\overline{X}$	11.32	35.08	53.00	31.84
	$\overline{SD}$	22.16	18.52	22.25	18.63
UNIT #6 MBC	$\overline{X}$	19.68	32.22	47.94	34.78
	$\overline{SD}$	22.73	18.40	20.82	15.49

soil between the two P&B treatments at the $\alpha = .05$ confidence level (Table 7, below). Similarly, there can be shown no apparent differences statistically for the amounts of slash and duff. There is a difference between the units in the data on vegetational competition (Table 6). Unit #1 P&B has only 26.36% total vegetational competition compared with 38.78% for unit #6 P&B and this difference is supported statistically. This may indicate a greater disturbance on unit #1 and, considering that lack of competition from other plant species may be influencial in the success of lodgepole pine regeneration, may explain partially differences in the amounts of regeneration.

TABLE 7

STATISTICAL ANALYSIS OF P&B TREATMENTS

$\alpha = .05$ confidence level using the t test
Ho: the P&B treatments are similar
(accept Ho: if $t < 1.645$; $\alpha = .05$)

Variable	t test value	Conclusion
mineral soil	t = 1.1227	accept Ho
duff	t = 0.8928	accept Ho
slash	t = 0.7729	accept Ho
vegetational competition	t = 3.1217	reject Ho

Marden Brush Cutter Treatments

When the data on mineral soil, mulch, and rock (Table 5) are combined for the MBC treatments the total for unit #1 MBC is 11.32%, while that for unit #6 MBC is 19.68% (Table 6). This difference is statistically significant at the $\alpha = .05$ confidence level (Table 8) and suggests the soil of unit #6 MBC to be more disturbed than the soil of unit #1 MBC. The data in Table 6 for the amounts of duff, slash, and vegetation associated with each unit are similar.

TABLE 8

STATISTICAL ANALYSIS OF MBC TREATMENTS

$\alpha = .05$ confidence level using the t test
Ho: the MBC treatments are similar
(accept Ho: if $t < 1.645; \alpha = .05$)

Variable	t test value	Conclusion
mineral soil	t = 1.8707	reject Ho
duff	t = 0.7859	accept Ho
slash	t = 1.1825	accept Ho
vegetational competition	t = 0.8761	accept Ho

Comparisons between MBC and P&B Treatments

Pooled data for both replicates of each treatment show means of 39.5% vs. 15.5% cover for mineral soil and 25.1% vs. 50.5% cover for slash on P&B and MBC treatments respectively. This is of course a reflection on the manner of manipulation for each treatment, one method (P&B) disturbing large amounts of soil and destroying most of the slash and the other method causing both little disturbance of soil and reduction of slash volumes. Pooled data of duff and vegetational cover for the two treatments show little difference, 37.6% vs. 33.6% duff cover on P&B and MBC treatments and 32.6% vs. 33.3% for vegetational cover. These similarities are a reflection of the large amounts of slash on the MBC treatments, which essentially make it impossible to measure relatively large amounts of vegetation and duff occurring beneath the slash.

Another interesting comparison is for the distribution of vegetation upon mineral and duff strata between the two treatments. The best way of presenting such a comparison is to use the data on primary and secondary site hits as presented in Table 9, page 54. As explained in the discussion on experimental design, a secondary hit represents the next hit on strata after the probe passes through vegetation. Therefore, secondary hits may be looked upon as strata, either mineral soil or duff, which supports or is occupied by some plant species. If the pointer hit strata without first striking vegetation, then this is considered a primary hit and the strata can be classified as supporting no vegetation. The sum of secondary hits on a certain strata, say mineral soil, is interpreted as the percent cover for vegetated mineral soil.

TABLE 9

SITE PREPARATION:
MEANS OF *PRIMARY & **SECONDARY HITS

*Primary hits- represent site hits that are unvegetated
**Secondary hits- represents site hits that are vegetated

	MINERAL		DUFF		SLASH	
	PRIMARY HITS	SECOND. HITS	PRIMARY HITS	SECOND. HITS	PRIMARY HITS	SECOND. HITS
#1 P&B	33.70	6.72	20.30	15.42	19.70	4.06
#6 P&B	25.98	6.80	17.22	21.40	18.10	8.26
#1 MBC	7.68	5.00	12.44	21.20	46.98	6.40
#6 MBC	13.50	5.36	12.28	19.98	38.32	9.38

This is easily converted to the percentage of mineral soil or duff that supports vegetation per treatment by dividing the number of secondary hits by the number of secondary plus primary hits on all of the fifty plots per treatment. Pooled data for each of the two treatments then shows that 18.3% of the mineral soil and 48.8% of the duff on the P&B treatments and 31.3% of the mineral soil and 61.0% of the duff on the MBC treatments supports vegetation. The soil of the P&B treatments is therefore more favorable to the establishment and survival of lodgepole pine seedlings on duff and especially mineral soil as compared to the MBC treatments.

III. REGENERATION AND MORTALITY

Influences of Timber Harvest and Site Preparation Timing on Seedling Emergence

The timing of the applications of timber harvest and site preparation techniques, and subsequently the exposure of serotinous cones to summer temperatures required for breakage of the resin seal, has a marked influence on amounts and timing of lodgepole pine seedling emergence. Each treatment replicate in this study was exposed to different timing sequences. A review of these events should show some of the variation that occurs between the measured regeneration on each treatment.

<u>Unit #1</u>. Logging was completed on this unit in January and February of 1967, creating seedbeds and exposing some serotinous cones to conditions favorable for opening during the warm summer. The seed shed from these cones germinated, following winter stratification, in the spring of 1968. Seven seedlings emerged on the plots of both unit #1 P&B and unit #1 MBC treatments in 1968 (Table 10, page 57) and are a result of similar logging operation effects.

Unit #1 P&B was piled in July of 1968 and burned in October of the same year (Table 2, page 36). Cones scattered over the P&B treatment during piling operations were exposed to favorable temperatures for breakage of the resin seal during the months of July and August of 1968, providing the seed for thirty-two 1969 germinating seedlings (Table 10). Only two seedlings emerged in 1970, indicating that regeneration is essentially complete on this P&B treatment replicate.

Unit #1 MBC was roller chopped in September of 1968. Serotinous cones did not open until the summer of 1969. The fifteen seedlings germinating in 1970 (Table 10) are a result of the 1968 treatment while those of 1969 (sixteen seedlings) are probably a result of the influence of logging. Since many unopened cones still remain on the slash, regeneration could continue for several more years.

Seedlings that germinated in 1967 or earlier (three-year or older seedlings in Table 10) are a result of natural regeneration before

TABLE 10: REGENERATION & MORTALITY DATA

The top figure in each box under "age classes" represents the number of seedlings found within the treatment plots before mortality. The lower figure represents the number of seedlings that were mortality.

Total established seedlings per acre & seedling frequencies are found in the last two columns.

TREAT-MENT	STRATA	AGE CLASSES: 3 YRS +		2 YRS (1968)		1 YRS (1969)		1970		ESTAB.-SDS/AC	SDLNG. FREQ.
		LPP	DF	LPP	DF	LPP	DF	LPP	DF		
UNIT #1 P&B	MINERAL	0 0	0 0	3 1	0 0	33 6	0 0	2 1	0 0	760	36%
	DUFF	0 0	0 0	4 1	1 0	9 4	0 0	0 0	0 0		
UNIT #6 P&B	MINERAL	0 0	0 0	5 0	0 0	7 2	0 0	9 4	0 0	460	20%
	DUFF	1 0	0 0	0 0	0 0	4 2	0 0	3 0	0 0		
UNIT #1 MBC	MINERAL	2 0	0 0	4 1	0 0	7 5	0 0	11 3	0 0	500	32%
	DUFF	3 0	0 0	3 0	0 0	9 7	0 0	4 2	0 0		
UNIT #6 MBC	MINERAL	1 0	0 0	3 0	1 0	10 3	0 0	35 11	0 0	960	34%
	DUFF	5 2	4 0	1 1	4 3	4 2	0 0	3 2	0 0		

logging. Five such seedlings were found on unit #1 MBC plots and none on the P&B plots. This is reasonable, considering that P&B treatment involves almost total disturbance of the site.

Unit #6. Logging was conducted on this unit in June and July of 1967. Seed from cones exposed to favorable temperatures for opening during the summer of 1967 and falling on favorable seedbeds germinated in 1968 and are the result of logging influences. Five seedlings emerged on unit #6 P&B plots and four on the MBC plots in 1968, showing similarities in the logging influences on the two treatments.

On unit #6 P&B the slash was piled in August of 1968 and burned in October. Some cones scattered about the unit during the piling process were exposed to favorable opening temperatures during the few remaining days of summer and were available for germination in 1969. However, many cones did not open until the following summer, 1969, and the seed germinated in the spring of 1970. Therefore, lodgepole seedlings established both in 1969 (11 seedlings) and 1970 (12 seedlings) are a result of treatment effects. Germination on this treatment should be complete at the present time.

Unit #6 MBC was treated with the rolling chopper in September of 1968. The cones did not open until the summer of 1969. The 38 seedlings germinated in 1970 are a result of the 1968 treatment while those of 1969 (14 seedlings) are still primarily a result of the influences of logging. Since many unopened cones are still contained on slash in this MBC unit, regeneration should continue for several years.

Factors Affecting Douglas-fir Regeneration

The large difference in second- and third-year (1968 and older) seedlings is interesting (Table 10). U.S.F.S. aerial photographs of the study units taken before logging were used to explain these differences. Here were discovered differences in the original stand densities and composition of the two units. Unit #1's topography is different from unit #6, with quite rolling terrain. Also, a ridge splits unit #1 that is the divide between Bogus and Gazelle Creeks. This ridge splits the unit into gentle north and south slopes. On the north slopes of unit #1, which is the MBC treatment, the photographs showed relatively pure stands of lodgepole pine. The southern exposure, which composes the P&B treatment, was more open and contained Douglas-fir in the overstory.

The topography of unit #6 is quite different, again being located on a ridge, but it is flat and sloping gently from NW to SE. The exposure of this unit is south facing except for a hill on the western edge of the cut. From the top of this hill, extending into both treatments, there was an open stand of lodgepole pine and very large Douglas-fir.

When using the brush chopper to treat slash, the machine tends to ride on top of the slash, disturbing the ground little.

Consequently, few of the seedlings present during the treatment were destroyed. Unit #6 MBC had an overstory containing Douglas-fir, which should explain the presence of older Douglas-fir seedlings. Why weren't there also a number of older Douglas-fir seedlings on units #1 and #6 P&B treatments? Here there was also a mixed stand. The pile and burn method of slash disposal involves almost complete disturbance of the site and most of the advanced regeneration was probably destroyed.

Results to be presented in the stump survey section will give support to the above observations on stand compositions and Douglas-fir regeneration.

Four, three-year and older and five 1968 Douglas-fir seedlings were found on unit #6 MBC plots (Table 10). None were found on this treatment in 1969 or 1970. One Douglas-fir seedling was found on unit #1 P&B plots and none for 1969 and 1970. A seed source for Douglas-fir does not exist within the clearcut blocks following treatment so that the only place new regeneration can be expected is within a few chains from the cut perimeter. 1968 and 1969 were apparent poor seed years for Douglas-fir, eliminating this possibility.

<u>Relative Regeneration Densities and Distributions</u>

Table 10 on page 57 presents information on numbers of established seedlings per acre and seedling frequencies (percent mill acre stocking) for the various treatments. On unit #1 and unit #6 P&B treatments there were found 760 and 460 established seedlings per acre and 36% vs. 20% mill acre stocking respectively. For MBC treatments, 500 vs. 960 seedlings per acre and 32% vs. 34% mill acre stocking were found for unit #1 MBC and unit #6 MBC. Statistical t-tests were conducted for comparisons of regeneration between treatments (Table 11). At the $\alpha = .05$ confidence level there was no significant differences between either the P&B or the MBC treatments.

TABLE 11

STATISTICAL ANALYSIS OF REGENERATION DATA

Ho' :the regeneration found on the P&B treatments are similar
Ho" :the regeneration on the MBC treatments are similar
Ho"':the pooled regeneration data for P&B treatments are similar to the pooled MBC treatment data
(accept Ho: if $t < 1.645$; $\alpha = .05$)

Variable	t test value	Conclusions
P&B regen.	$t = 1.151$	accept Ho'
MBC regen.	$t = 1.476$	accept Ho" (barely)
pooled MBC vs. pooled P&B regen.	$t = 0.6514$	accept Ho"'

Since the hypothesis of like results within treatments could not be rejected, it is appropriate to pool the regeneration data for MBC treatments for comparison to the results of pooled P&B data. The t-test again shows no significant difference at the $\alpha = .05$ confidence level (Table 11) so that we can not reject the hypothesis that the results of the regeneration between the two treatments are different. Therefore, there is no firm ground upon which this study can make recommendations of either P&B or MBC methods based on regeneration alone. They have similar results.

Percent mill acre stocking is probably one of the best indicators of the effectiveness of regeneration techniques. For lodgepole pine, a percent mill acre stocking of 50-65%, in combination with a seedling density of 500-650 seedlings per acre, should be optimum both in terms of growth of individual stems and in reducing expensive thinnings to a minimum. Regeneration would be scattered very uniformly about the treated area at such a stocking level. On all treatment replicates of this study the numbers of established seedlings per acre were similar to the optimum figure but the percent mill acre stocking was low. Regeneration in all cases has occurred in dense scattered patches. Thinnings will be required within most of these patches of regeneration and plantings will be needed in the understocked areas. Both the P&B and MBC treatments have failed in this objective.

Seedling Mortality

Seedling mortality data is summarized in Tables 10, 12 and 13. Table 10, page 57, shows specific relationships of mortality towards species of seedling, strata, total regeneration before mortality, and age class. Table 12, page 64, shows mortality by causal factor, strata, species, and age class. Tables 10 and 12 are summarized in Table 13. Seedling mortality should be the result of conditions in the micro-environment of individual seedlings and not the result of the type of treatment. The causes of mortality the past two summers were drought, consumption or burial by small animals, and unknown. The last chart in Table 13 gives a summary for mortality for all units combined. A total of 133 seedlings germinated on all plots on mineral soil and 62 on duff, leading to the opinion that mineral soil is a superior strata for lodgepole pine regeneration. Proceeding down the chart, we see a higher percentage for drought mortality on duff (38.7%) than for mineral soil (16.5%). Duff tends to retard penetration of rainfall into the mineral soil beneath. Seedling roots may not penetrate beyond this source of moisture and, when the duff dries out in late summer, the seedlings die. For the other causes of mortality we have higher percentages on mineral soil. Six percent of the seedlings were eaten by animals, ranging from Juncos to mice, 1.5% were buried by pocket gopher burrows, and 3.7% died from unknown causes on mineral soil. On duff, 1.6% of the seedlings died by burial and

TABLE 12

SEEDLING MORTALITY DATA
8" CIRCLE OF INFLUENCE COMBINED

		AGE CLASSES							
TREATMENT	MORTALITY FACTORS	3 yr.+		2 yr. (1968)		1 yr. (1969)		1970	
		MIN	DUFF	MIN	DUFF	MIN	DUFF	MIN	DUFF
#1 P&B	DROUGHT	0	0	1	1	1	3	1	0
	EATEN	0	0	0	0	1	0	0	0
	BURIED	0	0	0	0	2	1	0	0
	UNKNOWN	0	0	0	0	2	0	0	0
#6 P&B	DROUGHT	0	0	0	0	1	2	4	0
	EATEN	0	0	0	0	0	0	0	0
	BURIED	0	0	0	0	0	0	0	0
	UNKNOWN	0	0	0	0	1	0	0	0
#1 MBC	DROUGHT	0	0	0	0	1	6	3	2
	EATEN	0	0	0	0	4	0	0	0
	BURIED	0	0	0	0	0	0	0	0
	UNKNOWN	0	0	1	0	0	1	0	0
#6 MBC	DROUGHT	0	2	0	4	0	2	10	2
	EATEN	0	0	0	0	3	0	0	0
	BURIED	0	0	0	0	0	0	0	0
	UNKNOWN	0	0	0	0	0	0	1	0

TABLE 13

SUMMARY OF MORTALITY CAUSAL FACTORS: 1969, 1970, & OVERALL (1965-1970)

Notice the percentages showing the relationship of the various types of mortality towards their strata.

	1969 SUMMARY		1970 SUMMARY		OVERALL SUMMARY 1965-1970	
STRATA	MINERAL	DUFF	MINERAL	DUFF	MINERAL	DUFF
TOTAL GERMINATED SEEDLINGS	57(68.7%)	26(31.3%)	57(85.1%)	10(14.9%)	133(68.2%)	62(31.8%)
TOTAL MORTALITY	16(28.1%)	15(57.7%)	19(33.3%)	4(40.0%)	37(27.8%)	26(41.9%)
DROUGHT MORTALITY	3(5.3%)	13(50.0%)	18(31.6%)	4(40.0%)	22(16.5%)	24(38.7%)
EATEN MORTALITY	8(14.0%)	0	0	0	8(6.0%)	0
BURIED MORTALITY	2(3.5%)	1(3.8%)	0	0	2(1.5%)	1(1.6%)
UNKNOWN MORTALITY	3(5.2%)	1(3.8%)	1(1.8%)	0	5(3.76%)	1(1.6%)

1.6% by unknown causes. These differences can be attributed to easier animal access to seedlings due to the open nature of cover on mineral soil.

The other two charts of Table 13 show the difference between 1969 and 1970 mortality. Most important is the difference in drought mortality occurring on mineral soil for the two years. This amounted to only 5.3% in 1969 as compared to 31.6% in 1970. This shows 1970 to be an extremely dry season in comparison to 1969, with soil moisture conditions being critical even on mineral soil. Data presented in the results section for weather confirm this observation. Total precipitation for the critical months of June, July, and August of 1970 was only 4.85 inches as compared to 7.65 inches for 1969, a year in which drought mortality was minimal on mineral soil.

IV. STUMP SURVEY

The data for merchantable timber on the study units are presented in Table 14, page 67. Treatments #1 P&B and #6 MBC had relatively high amounts of commercial Douglas-fir in comparison with the other two treatments. This lends support to arguments on Douglas-fir regeneration presented in the discussion of regeneration results, page 59. The numbers of seed per acre contained in serotinous cones on commercial timber shows the seed source to be very large on all treatments. The method used for the determination of seed numbers (page 44) was not very accurate so that the figures given can not be used for any inferences towards established regeneration on the two treatments.

TABLE 14

STUMP SURVEY

Measurements of stumps eight inches and larger diameter converted to basal area per acre and number of lodgepole pine seed contained in serotinous cones per acre.

Treatment	Basal area (sq. ft.)	Seed/acre
#1 P&B	LPP-76.58 DF 14.44	2,846,400
#1 MBC	LPP-86.65 DF-5.80	4,437,900
#6 P&B	LPP-67.85 DF-3.01	2,333,900
#6 MBC	LPP-80.04 DF-16.98	2,834,900

CHAPTER VI

DISCUSSION

I. FIELD TECHNIQUES

Pre-treatment Stand Inventory

This study was initiated following completion of logging and slash treatment on the clearcut units. Elimination of a survey of stand conditions and compositions as they existed before silvicultural prescription is the largest error associated within the study. Such a survey would have provided valuable information on stand structure and function. The distribution of stand growth patterns, such as density, age, and size classes, could have been correlated with the results of site preparation and regeneration on both the pile and burn and brush cutter treatments. Additional measurements on the incidence of cone serotiny would have provided information for correlation with patterns of regeneration on the units.

Plot Location

On unit #6 one line was used for plot location on each of the treatments. This was believed to be sufficient due to the homogeneous nature of the topography of the unit. However, during the collection of data during the past two summers, it was recognized that considerable variation within this unit in soils and in the original overstory composition warranted more thorough plot coverage. A proper survey of the original stand conditions would have shown this variation and suggested a different sampling technique. A grid system of plot location might have been used on this unit, providing more efficient coverage of the existing variation.

Unit #1 had two lines of plots established on each treatment. It appears that the established plots probably provided for sampling of most of the variation existing on the treatments.

Number of Replicates

Admittedly, having only two replicates of each treatment limits the scope of the conclusions this study may express. More time and support would have allowed sampling of more units with varying aspects, slopes, elevations, and stand compositions.

Site Preparation Measurements

Original measurements of site preparation included estimates of the amounts of mineral soil, mulch, rock, duff, slash, and vegetation. As expressed in site preparation results, mulch should have been classified as mineral soil due to difficulties of interpretation among investigators. In addition, measurements of mineral soil should have included a category for burned mineral soil occurring on P&B treatments. Visual estimates showed #1 P&B and #6 P&B treatments to be similar as to the amounts of soil exposed where piles were burned (approximately 9% vs. 8% respectively). In addition, unit #1 P&B had a rather extensive area where an uncontrolled ground fire exposed some mineral soil (approximately 7%). Regeneration cannot be expected on these burned areas due to the destruction of seed by the fire. In fact, only one seedling was observed to emerge on burned soil. Therefore, the effective mineral soil in respect to regeneration should be the amount expressed in the site preparation tables minus the unrecorded amounts of burned mineral soil. This amount would be similar for the two P&B treatments.

Measurements of duff should have been subdivided into disturbed and undisturbed duff. Disturbed duff, due to destruction of vegetational competition, should be more conducive to establishment regeneration.

Subdivisions of slash should have included measurements of size and depth. Some plots, containing a rather thin scattering of twigs, needles, and cones, received similar estimates of slash cover as plots covered with deep accumulations of branches and logs. Regeneration can be expected on the former plot but is impossible on the latter.

II. COMPARISONS OF TREATMENTS

Site Preparation

Within P&B treatments. There was found to be only one difference among the variables of site preparation on the P&B treatments. This difference was in the amounts of vegetation. Several reasons could be responsible for this difference. First, there could have been real differences in treatment effects, a greater disturbance on unit #1, P&B destroying more of the vegetation. Secondly, the greater degree of burning on unit #1, due to the uncontrolled ground fire, destroyed additional amounts of vegetation. It is probably true that a combination of these factors is responsible. The only other noticeable difference in site preparation variables was in the amount of mineral soil on the two P&B treatments. However, this difference was not significant statistically. The only real difference was probably due to the same ground fire's exposure of additional amounts of mineral soil.

Within MBC treatments. Within the MBC treatments the only significant difference in site preparation variables was in the amount of mineral soil. All other variables were similar. Whether this difference is attributable to differences in the amounts of mineral soil exposed during logging or slash treatment cannot be determined. However, considering the very similar results for the other variables, the effects of logging might be more influential. Even then, the overall effect is what is important, as mineral soil is influential on regeneration regardless of its source.

Between the MBC and P&B treatments. There are very large differences in the site preparation effects between the MBC and P&B treatments. Considering the techniques of slash treatment involved, these results are not surprising. The brush cutter disturbs the soil little and leaves large amounts of slash while the pile and burn treatment has opposite effects.

The regeneration triangle expresses the three factors necessary for successful regeneration: seed source, seedbed, and conditions favorable to survival. The P&B treatment shows high amounts of mineral soil, providing ample seedbeds and a suitable moisture regime for survival of seedlings, and relatively low amounts of seed in relation to the triangle. The inverse is true with MBC treatments, there being little exposure of proper seedbeds but immense supplies of seed contained in serotinous cones contained on slash. However, it is not the relative proportions of each of the three factors, but the correlation of all three that determines the success of regeneration on a treatment. This success is expressed by the amount of regeneration that becomes established on the various treatments.

Regeneration and Mortality

Results have shown there to be no differences in established regeneration within treatments. Table 15, page 73, shows pooled data for germinated seedlings on P&B and MBC treatments. Eighty-one seedlings emerged on P&B treatments, of which 21, or 25.9%, died. On MBC treatments 114 seedlings emerged, of which 42 died, or 36.8%. The smaller numbers of seedlings that emerged on P&B treatments is a reflection of a smaller seed source, much of the seed being destroyed in the burning process. On MBC treatments seed sources were large, resulting in larger amounts of germinated seedlings despite relatively small quantities of mineral soil. At this point the third factor of the regeneration triangle becomes important, conditions favorable to survival. Results have shown the mineral and duff soils of the P&B treatments to support considerably less vegetation than the MBC treatments. This, along with large quantities of slash and undisturbed duff, resulted in higher rates of mortalities for MBC seedlings (Table 15). The overall result is that there can be shown no statistical difference between the two treatments in their amounts of successful established regeneration. Different factors of input into the regeneration triangle have resulted in similar overall effects in the success of regeneration.

TABLE 15

POOLED MORTALITY DATA WITHIN TREATMENTS

Treatments	Number of Germinated Seedlings	No. of Seedlings becoming Mortality
P&B	81	21 or 25.9%
MBC	114	42 or 36.8%

CHAPTER VII

CONCLUSIONS

Since regeneration for MBC and P&B treatments has been shown to be similar, other factors need to be considered in choosing between P&B and MBC methods of slash disposal in lodgepole pine stands. These may include original stand composition, economics, fire hazard, air polution, and aesthetics.

Stand composition has a marked effect on the efficiency of the brush chopper. In natural stands of timber in the western states there is typically a large residual volume of slash following logging. This is particularly true with lodgepole pine stands. When treating an area of heavy slash accumulation with the brush chopper the tractor and cutter are forced to ride on top of several feet of springy slash and the cutting action of the blades is reduced. The results of such a situation are illustrated graphically in Plate 17, page 75. Such an area is unfit for man, beast, or regeneration, and will be a high fire hazard for many years. Until the day comes when lodgepole pine stands are under management producing little waste in unmerchantable size classes the brush chopper should be restricted to use in those situations where there is little residual slash volumes. Silvicultural methods such as piling and burning will need to be used in cases where heavy residual slash volumes exist.

PLATE 17

AN AREA OF HEAVY SLASH ACCUMULATION TREATED WITH THE MARDEN BRUSH CUTTER

The profession of forestry has entered an era in which public opinion will be a deciding factor in the management techniques applied to the utilization of our forest resources. No longer can the forester proceed in his small world of self-conceit, ignoring the feelings and wishes of the common man. Air polution is an everyday word which may spell the doom of prescribed burning. Aesthetics may bring an end to the practice of clearcutting. The point is this: the brush cutter is only one method used in the management of our forest lands. What methods are to be used must be based on ecological common sense, with an eye to the will of the public. The brush cutter has its place in the management of our forest lands. Please don't abuse that privilege.

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